Light Emitting Display, Display Pan l, and Driving Method ther of

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority to and the benefit of Korea Patent Application No. 2003-20434 filed on April 1, 2003 in the Korean Intellectual Property Office, the content of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

(a) Field of the Invention

The present invention relates to a light emitting display, a display panel, and a driving method thereof. More specifically, the present invention relates to an organic electroluminescent (EL) display.

(b) Description of the Related Art

In general, an organic EL display electrically excites a phosphorous organic compound to emit light, and it voltage- or current-drives NxM organic emitting cells to display images. As shown in FIG. 1, an organic emitting cell includes an anode of indium tin oxide (ITO), an organic thin film, and a cathode layer of metal. The organic thin film has a multi-layer structure including an emitting layer (EML), an electron transport layer (ETL), and a hole transport layer (HTL) for maintaining balance between electrons and holes and improving emitting efficiencies, and it further includes an electron injecting layer (EIL) and a hole injecting layer (HIL).

Methods for driving the organic emitting cells include the passive matrix

method, and the active matrix method using thin film transistors (TFTs) or metal oxide semiconductor field effect transistors (MOSFETs). The passive matrix method forms cathodes and anodes to cross with each other, and selectively drives lines. The active matrix method connects a TFT and a capacitor with each ITO pixel electrode to thereby maintain a predetermined voltage according to capacitance. The active matrix method is classified as a voltage programming method or a current programming method according to signal forms supplied for maintaining a voltage at a capacitor.

Referring to FIGs. 2 and 3, conventional organic EL displays of the voltage programming and current programming methods will be described.

FIG. 2 shows a conventional voltage programming type pixel circuit for driving an organic EL element, representing one of NxM pixels. Referring to FIG. 2, transistor M1 is coupled to an organic EL element (referred to as an OLED hereinafter) to thus supply current for light emission. The current of transistor M1 is controlled by a data voltage applied through switching transistor M2. In this instance, capacitor C1 for maintaining the applied voltage for a predetermined period is coupled between a source and a gate of transistor M1. Scan line S_n is coupled to a gate of transistor M2, and data line Dm is coupled to a source thereof.

As to an operation of the above-configured pixel, when transistor M2 is turned on according to a select signal applied to the gate of switching transistor M2, a data voltage from data line Dm is applied to the gate of the transistor M1. Accordingly, current I_{OLED} flows to transistor M2 in correspondence to a voltage V_{GS} charged between the gate and the source by C1, and the OLED emits light

in correspondence to current I_{OLED}.

In this instance, the current that flows to the OLED is given in Equation 1.

Equation 1

$$I_{OLED} = \frac{\beta}{2}(V_{GS} - V_{TH})^2 = \frac{\beta}{2}(V_{DD} - V_{DATA} - |V_{TH}|)^2$$

where I_{OLED} is the current flowing to the OLED, V_{GS} is a voltage between the source and the gate of the transistor M1, V_{TH} is a threshold voltage at transistor M1, and β is a constant.

As given in Equation 1, the current corresponding to the applied data voltage is supplied to the OLED, and the OLED gives light in correspondence to the supplied current, according to the pixel circuit of FIG. 2. In this instance, the applied data voltage has multi-stage values within a predetermined range so as to represent gray.

However, the conventional pixel circuit following the voltage programming method has a problem in that it is difficult to obtain high gray because of deviation of a threshold voltage V_{TH} of a TFT and deviations of electron mobility caused by non-uniformity of an assembly process. For example, in the case of driving a TFT of a pixel with 3 volts (3V), voltages are to be supplied to the gate of the TFT for each interval of 12mV (=3V/256) so as to represent 8-bit (256) grays, and if the threshold voltage of the TFT caused by the non-uniformity of the assembly process deviates, it is difficult to represent high gray. Also, since the value β in Equation 1 changes because of the deviations of the electron mobility, it becomes even more difficult to represent

the high gray.

On assuming that the current source for supplying the current to the pixel circuit is uniform over the whole panel, the pixel circuit of the current programming method can achieve uniform display features even though a driving transistor in each pixel has non-uniform voltage-current characteristics.

FIG. 3 shows a pixel circuit of a conventional current programming method for driving the OLED, representing one of NxM pixels. Referring to FIG. 3, transistor M1 is coupled to the OLED to supply the current for light emission, and the current of transistor M1 is controlled by the data current applied through transistor M2.

First, when transistors M2 and M3 are turned on because of the select signal from scan line S_n, transistor M1 becomes diode-connected, and the voltage matched with data current I_{DATA} from data line Dm is stored in capacitor C1. Next, the select signal from scan line S_n becomes high-level to turn on transistor M4. Then, the power is supplied from power supply voltage VDD, and the current matched with the voltage stored in capacitor C1 flows to the OLED to emit light. In this instance, the current flowing to the OLED is as follows.

Equation 2

$$I_{OLED} = \frac{\beta}{2}(V_{GS} - V_{TH})^2 = I_{DATA}$$

where V_{GS} is a voltage between the source and the gate of transistor M1, V_{TH} is a threshold voltage at transistor M1, and β is a constant.

As given in Equation 2, since current I_{OLED} flowing to the OLED is the same as data current I_{DATA} in the conventional current pixel circuit, uniform

characteristics can be obtained when the programming current source is set to be uniform over the whole panel. However, since current I_{OLED} flowing to the OLED is a fine current, control over the pixel circuit by fine current I_{DATA} problematically requires much time to charge the data line. For example, assuming that the load capacitance of the data line is 30pF, it requires several milliseconds of time to charge the load of the data line with the data current of several tens to hundreds of nA. This causes a problem that the charging time is not sufficient in consideration of the line time of several tens of microseconds.

SUMMARY OF THE INVENTION

In accordance with the present invention a light emitting display is provided for compensating for the threshold voltage of transistors or for electron mobility, and sufficiently charging the data line.

In one aspect of the present invention, a light emitting display is provided on which a plurality of data lines for transmitting data current that displays video signals, a plurality of scan lines for transmitting a select signal, and a plurality of pixel circuits formed at a plurality of pixels defined by the data lines and the scan lines are formed. The pixel circuit includes: a light emitting element for emitting light corresponding to the applied current; a first transistor, having first and second main electrodes and a control electrode, for supplying a driving current for the light emitting element a second transistor being diode-connected; a first switch for transmitting a data current from the data line to the second transistor in response to a select signal from the scan line; a first

storage element having a first end coupled to the first main electrode of the first transistor and a first main electrode of the second transistor, and a second end thereof coupled to the control electrode of the first transistor, the second end being coupled to a gate of the second transistor in response to a first level of a first control signal; a second storage element coupled between the second end of the first storage element and a control electrode of the second transistor in response to a second level of the first control signal; and a second switch for coupling the first transistor and the light emitting element in response to a second control signal. The light emitting display operates in the order of a first interval for selecting the first level of the first control signal and the select signal, a second interval for selecting the second level of the first control signal, and a third interval for selecting the second control signal. The voltage of the control electrode of the second transistor is determined as a first voltage in correspondence with the data current in the first interval. A control electrode voltage of the second transistor is changed to a second voltage from the first voltage by the interception of the data current. A control electrode voltage of the first transistor is determined as a third voltage by coupling of the first and second storage elements to store a fourth voltage in the first storage element in the second interval. A driving current corresponding to the fourth voltage is transmitted to the light emitting element from the first transistor in the third interval. The pixel circuit further includes a third switch coupled between the control electrodes of the first and second transistors. The third switch is turned on by the first level of the first control signal. The first control signal is the select signal. The first control signal is supplied from an additional signal line other

than the scan line, and the first control signal has faster timing than the select signal. A channel width of the first transistor is equal to or shorter than the channel width of the second transistor. A channel length of the first transistor is equal to or longer than the channel width of the second transistor. The first storage element is a first capacitor formed between the first main electrode and the control electrode of the first transistor. The second storage element is a second capacitor formed between the control electrodes of the first and second transistors. Capacitance of the first capacitor and capacitance of the second capacitor is determined by one of a screen size and resolution. Uniformity between the threshold voltages of the first and second transistors is high.

In another aspect of the present invention, a method is provided for driving a light emitting display having a pixel circuit including a first switch for transmitting a data current from a data line in response to a select signal from a scan line, a first transistor including first and second main electrodes and a control electrode for outputting a driving current corresponding to the data current, a first storage element formed between the first main electrode and the control electrode of the first transistor, and a light emitting element for emitting light corresponding to the driving current from the first transistor. The control electrode of the diode-connected second transistor is coupled to the control electrode of the first transistor. The data current is transmitted from the first switch to the second transistor to establish the control electrode voltage of the second transistor as a first voltage. A second storage element is formed between the control electrodes of the first and second transistors. Data current is intercepted to modify the first voltage into a second voltage to which a

threshold voltage of the second transistor is reflected. Coupling of the second voltage and the first and second storage elements is used to modify the control electrode voltage of the first transistor into a third voltage from the first voltage. A driving current output is transmitted by the first transistor to the light emitting element corresponding to the third voltage.

In still another aspect of the present invention, a display panel of a light emitting display is provided, on which are formed a plurality of data lines for transmitting the data current that displays video signals, a plurality of scan lines for transmitting a select signal, and a plurality of pixel circuits formed at a plurality of pixels defined by the data lines and the scan lines. The pixel circuit includes: a light emitting element for emitting light corresponding to the applied current; a first transistor having first and second main electrodes and a control electrode, for supplying a driving current for emitting light from the light emitting element; a second transistor being diode-connected; a first switch for transmitting a data current from the data line to the second transistor in response to a select signal from the scan line; a first storage element coupled to the control electrode of the first transistor; and a second storage element. The display panel operates in the order of: a first interval for coupling control electrodes of the first and second transistors, and storing voltage in the first storage element corresponding to a data current from the first switch; a second interval for forming a second storage element between the control electrodes of the first and second transistors, and intercepting the data current to divide a voltage corresponding to a threshold voltage of the second transistor into the first and second storage elements; and a third interval for transmitting a driving

current output by the first transistor to the light emitting element corresponding to the voltage stored in the first storage element. The control electrodes of the first and second transistors are coupled in response to a first-level first control signal. The data current is transmitted to the second transistor in response to the select signal in the first interval. The second storage element is coupled between the control electrodes of the first and second transistors in response to a second-level first control signal. The select signal becomes a disable level to intercept the data current in the second interval. The driving current is transmitted to the light emitting element in response to a second control signal in the third interval.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a concept diagram of an OLED.

FIG. 2 shows an equivalent circuit of a conventional pixel circuit following the voltage programming method.

FIG. 3 shows an equivalent circuit of a conventional pixel circuit following the current programming method.

FIG. 4 shows a brief plane diagram of an organic EL display according to an embodiment of the present invention.

FIGs. 5 and 7 respectively show an equivalent circuit of a pixel circuit according to first and second embodiments of the present invention; and

FIGs. 6 and 8 respectively show a driving waveform for driving the pixel circuit of FIGs. 5 and 7.

DETAILED DESCRIPTION

An organic EL display, a corresponding pixel circuit, and a driving method thereof will be described in detail with reference to drawings.

First, referring to FIG. 4, the organic EL display will be described. FIG. 4 shows a brief ground plan of the OLED.

As shown, the organic EL display includes organic EL display panel 10, scan driver 20, and data driver 30.

Organic EL display panel 10 includes a plurality of data lines D_1 through D_m in the row direction, a plurality of scan lines S_1 through S_n and E_1 through E_n, and a plurality of pixel circuits 11. Data lines D_1 through D_m transmit data signals that represent video signals to pixel circuit 11, and scan lines S_1 through S_n transmit select signals to pixel circuit 11. Pixel circuit 11 is formed at a pixel region defined by two adjacent data lines D_1 through D_m and two adjacent scan lines S_1 through S_n. Also, scan lines E_1 through E_n transmit emit signals for controlling emission of the pixel circuits 11.

Scan driver 20 sequentially applies respective select signals and emit signals to the scan lines S_1 through S_n and E_1 through E_n. Data driver 30 applies the data current that represents video signals to the data lines D_1 through D_m.

Scan driver 20 and/or data driver 30 can be coupled to display panel 10, or can be installed, in a chip format, in a tape carrier package (TCP) coupled to display panel 10. The same can be attached to display panel 10, and installed,

in a chip format, on a flexible printed circuit (FPC) or a film coupled to the display panel 10, which is referred to as a chip on flexible board, or chip on film (CoF) method. Differing from this, scan driver 20 and/or data driver 30 can be installed on the glass substrate of the display panel, and further, the same can be substituted for the driving circuit formed in the same layers of the scan lines, the data lines, and TFTs on the glass substrate, or directly installed on the glass substrate, which is referred to as a chip on glass (CoG) method.

Referring to FIGs. 5 and 6, pixel circuit 11 of the organic EL display according to the first embodiment of the present invention will now be described. FIG. 5 shows an equivalent circuit diagram of the pixel circuit according to the first embodiment, and FIG. 6 shows a driving waveform diagram for driving the pixel circuit of FIG. 5. In this instance, for ease of description, FIG. 5 shows a pixel circuit coupled to an m-th data line D_m and an n-th scan line S_n.

As shown in FIG. 5, pixel circuit 11 includes an OLED, PMOS transistors M1 through M5, and capacitors C1 and C2. The transistor is preferably a transistor having a gate electrode, a drain electrode, and a source electrode formed on the glass substrate as a control electrode and two main electrodes.

Transistor M1 has a source coupled to power supply voltage VDD, and a gate coupled to capacitor C2, and capacitor C1 is coupled between the gate and the source of transistor M1. A gate and a drain of transistor M2 are coupled, that is, diode-connected, and a source of transistor M2 is coupled to power supply voltage VDD. Transistor M5 and capacitor C2 are coupled in parallel between the gate of transistor M2 and the gate of transistor M1.

Transistor M3 transmits data current I_{DATA} from data line D_m to transistor M2 in response to select signal SE_n from scan line S_n. Transistor M5 couples the gate of transistor M2 to the gate of transistor M1 in response to select signal SE_n from scan line S_n. Transistor M4 is coupled between the drain of transistor M1 and the OLED, and transmits current I_{OLED} of transistor M1 to the OLED in response to emit signal EM_n from scan line E_n. The OLED is coupled between transistor M4 and the reference voltage, and emits light corresponding to applied I_{OLED}.

Next, referring to FIG. 6, an operation of the pixel circuit according to the first embodiment of the present invention will be described in detail.

As shown, in interval T1, transistor M5 is turned on by low-level select signal SE_n to couple the gate of transistor M1 and the gate of transistor M2. Transistor M3 is turned on by select signal SE_n to have data current I_{DATA} from data line D_m flow to transistor M2. Data current I_{DATA} can be given as Equation 3, and the gate voltage $V_{G3}(T1)$ at transistor M2 in interval T1 is determined from Equation 3. Since the gate of transistor M1 and the gate of transistor M2 are coupled, the gate voltage $V_{G1}(T1)$ at transistor M1 corresponds to the gate voltage $V_{G3}(T1)$ at transistor M2.

Equation 3

$$I_{DATA} = \frac{1}{2}\mu_2 C_{ox2}\frac{W_2}{L_2}(V_{GS} - V_{TH2})^2 = \frac{1}{2}\mu_2 C_{ox2}\frac{W_2}{L_2}(V_{DD} - V_{G2}(T1) - |V_{TH2}|)$$

where μ_2 is electron mobility, C_{ox2} is oxide capacitance, W_2 is a channel width, L_2 is a channel length, V_{TH2} is a threshold voltage of transistor M2, and V_{DD} is a voltage supplied to transistor M2 by power supply voltage

VDD.

In interval T2, select signal SE_n becomes high-level to turn off transistors M3 and M5. Data current I_{DATA} is intercepted by turned-off transistor M3, and since transistor M2 is diode-connected, the gate voltage $V_{G2}(T2)$ of transistor M2 becomes $V_{DD} - |V_{TH2}|$. Therefore, the variation ΔV_{G2} of the gate voltage of transistor M2 between intervals T1 and T2 is given as Equation 4. Since the gate voltage $V_{G1}(T2)$ of transistor M1 corresponds to a node voltage of capacitors C1 and C2 coupled in series, the variation ΔV_{G1} of the gate voltage of transistor M1 is given as Equation 5. That is, the gate voltage $V_{G1}(T2)$ of transistor M1 becomes $V_{G1}(T1) + \Delta V_{G1}$.

Equation 4

$$\Delta V_{G2} = V_{G2}(T2) - V_{G2}(T1) = V_{DD} - |V_{TH2}| - V_{G2}(T1)$$

Equation 5

$$\Delta V_{G1} = \frac{C_1}{C_1 + C_2} \Delta V_{G2} = \frac{C_1}{C_1 + C_2} (V_{DD} - |V_{TH2}| - V_{G2}(T1))$$

where C_1 and C_2 are capacitances of capacitors C1 and C2.

In interval T3, transistor M4 is turned on in response to low-level emit signal EM_n. Current I_{OLED} flowing to transistor M1 flows to the OLED by turned-on transistor M4 to emit light, and current IOLED in this instance is given as Equation 6.

Equation 6

$$I_{OLED} = \frac{1}{2}\mu_1 C_{ox1}\frac{W_1}{L_1}(V_{DD} - V_{G1}(T2) - |V_{TH1}|)^2$$
$$= \frac{1}{2}\mu_1 C_{ox1}\frac{W_1}{L_1}\left\{V_{DD} - \frac{C_1}{C_1 + C_2}\left(V_{DD} - |V_{TH2}| - V_{G2}(T1)\right) - V_{G2}(T1) - |V_{TH1}|\right\}^2$$

where μ_1 is electron mobility, C_{ox1} is oxide capacitance, W_1 is a channel width, L_1 is a channel length, and V_{TH1} is a threshold voltage of transistor M1.

Since transistors M1 and M2 are adjacently formed in a small pixel, uniformity between the electron mobility μ_1 and μ_2, the threshold voltages V_{TH1} and V_{TH2}, and the oxide capacitances C_{ox1} and C_{ox2} improves, and hence they are substantially identical with each other (i.e., μ_1 = μ_2, V_{TH1} = V_{TH2}, and C_{ox1} = C_{ox2}). Therefore, Equation 6 can also be expressed as Equation 7, and Equation 7 can be given as Equation 8 using Equation 3.

Equation 7

$$I_{OLED} = \frac{1}{2}\mu_1 C_{ox1}\frac{W_1}{L_1}\cdot\frac{C_2}{C_1 + C_2}(V_{DD} - V_{G2}(T1) - |V_{TH2}|)^2$$

Equation 8

$$I_{OLED} = \frac{W_1}{L_1}\cdot\frac{L_2}{W_2}\left(\frac{C_2}{C_1 + C_2}\right)I_{DATA}$$

In this instance, if the capacitance C_1 of capacitor C1 is n times the capacitance C_2 of capacitor C2 (i.e., C_1=n C_2), and the ratio W_2 / L_2 of the channel width and the channel length of transistor M2 is M times the ratio W_1 / L_1 of the channel width and the channel length of transistor M1, Equation 8 is given as Equation 9. In particular, it is preferable that the channel width W_2 of

transistor M2 is equal to or longer than the channel width W_1 of transistor M1, and the channel length L_2 of transistor M2 is equal to or shorter than the channel length L_1 of transistor M1. It is also preferable to optimize the ratio of the capacitance C_1 of capacitor C1 and the capacitance C_2 of capacitor C2 according to the size and resolution of a screen.

Equation 9

$$I_{OLED} = \frac{1}{M(n+1)} I_{DATA}$$

As given in Equation 9, since current I_{OLED} supplied to the OLED is determined with no relation to the threshold voltage V_{TH1} or the electron mobility μ_1 of transistor M1, the deviation of the threshold voltage or the mobility can be corrected. Also, since current I_{OLED} is controlled by current I_{DATA} which is M(n+1) times greater than current I_{OLED} supplied to the OLED, high gray can be represented. Further, since large data current I_{DATA} is supplied to data lines D_1 through D_m, the time for charging the data lines can be sufficiently obtained, and a wide OLED can be realized. In addition, since transistors M1 through M5 are the same type, the process for forming the TFTs on the glass substrate can be easily executed.

In the first embodiment, PMOS transistors are used to realize transistors M1 through M5, and NMOS transistors can also be applied. In the case of realizing transistors M1 through M5 through the PMOS transistors, the sources of transistors M1 and M2 are coupled not to power supply voltage VDD but to the reference voltage, a cathode of the OLED is coupled to transistor M4,

and an anode thereof is coupled to power supply voltage VDD in the pixel circuit of FIG. 5. The waveforms of select signal SE_n and emit signal EM_n have inverted formats of those in FIG. 6. Since realization of transistors M1 through M5 using the NMOS transistors can be easily known from the description according to the first embodiment, no further description will be provided. Also, transistors M1 through M5 can be realized by combination of PMOS and NMOS transistors or switches having similar functions.

In the first embodiment, transistor M5 is controlled using select signal SE_n from scan line S_n, but it can be controlled using a control signal from an additional scan line, which will now be described referring to FIGs. 7 and 8.

FIG. 7 shows an equivalent circuit of a pixel circuit according to a second embodiment of the present invention, and FIG. 8 shows a driving waveform for driving the pixel circuit of FIG. 7.

As shown in FIG. 7, the pixel circuit according to the second embodiment further includes scan line C_n in the pixel circuit of FIG. 5. Transistor M5 has a gate coupled to scan line C_n, and couples the gate of transistor M1 to the gate of transistor M2 in response to control signal CS_n from scan line C_n.

Referring to FIG. 8, since turn-on and turn-off timing problem of transistors M3 and M5 can occur in the first embodiment, control signal CS_n is set to be low-level prior to select signal SE_n. In this instance, a delayed signal of control signal CS_n can be used as a select signal SE_n.

In detail, transistor M5 is previously turned on by control signal CS_n to couple the gate of transistor M1 and the gate of transistor M2, and transistor

M3 is turned on by select signal SE_n to transmit data current I_{DATA}. Transistor M5 is turned off by high-level control signal CS_n to charge capacitors C1 and C2 with voltage, and transistor M3 is turned off by high-level select signal SE_n to intercept data current I_{DATA}. Since the operation of the pixel circuit according to the second embodiment is similar to that of the first embodiment, no detailed description thereof will be provided.

According to the present invention, since the current flowing to the OLED can be controlled by a large data current, the data line can be sufficiently charged for a single line time, the deviation of the threshold voltage or the mobility is corrected, and a light emitting display with high resolution and wide screen can be realized.

While this invention has been described in connection with what is presently considered to be practical embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.